

Introduction

Science has direct application to nearly all aspects of life and society, from maintaining and improving human health to understanding and solving local, regional, and global environmental issues. Students need early development in science knowledge and thinking skills not only to be thoughtful citizens engaged in public discussions on important social issues involving science, but also to be prepared to make contributions through a wide range of careers in science, medicine, and technology. Thus, the study of science in the primary and early secondary grades provides a critical foundation for students' future careers and life success.

TIMSS (Trends in International Mathematics and Science Study) has the goal of helping countries make informed decisions about how to improve teaching and learning in mathematics and science. This TIMSS 2011 report summarizes the results of the TIMSS 2011 international science assessment of fourth and eighth grade students in countries around the world. As the fifth assessment in a regular program of student assessment conducted every four years since 1995, TIMSS 2011 provides participating countries with a wealth of information about trends in the science knowledge and skills of their students. At the heart of TIMSS is a wide-ranging state-of-the-art assessment of how well students master the essential science content, concepts, and procedures that countries expect them to learn as they progress through primary and lower secondary school.

Student achievement on the TIMSS 2011 science assessment is summarized in a variety of ways, beginning with trends over time in science achievement overall as well as its major component parts (e.g., biology, chemistry). The results also monitor progress toward the TIMSS International Benchmarks of science achievement—advanced, high, intermediate, and low. Recognizing that student science achievement is the result of a complex interplay of societal, school, and home environmental factors, this TIMSS science report embeds the achievement results in the context of the major influences on student learning, including the scope and coverage of the science curriculum, home support for student learning, school resources and learning climate, teacher preparation for science instruction, and student engagement in classroom learning.

Countries Participating in TIMSS 2011

IEA is an independent international cooperative of national research institutions and government agencies with nearly 70 member countries worldwide. IEA has a permanent secretariat based in Amsterdam, and a thriving data processing and research center in Hamburg (the IEA DPC). The decision to participate in an IEA study is coordinated through the IEA Secretariat in Amsterdam and made solely by each member country according to its own data needs and resources.

Exhibit 1 shows the 63 countries participating in TIMSS 2011, including some distinct education systems within countries that have always participated separately throughout IEA's long history (e.g., the Flemish-speaking part of Belgium and Hong Kong SAR). In addition, TIMSS 2011 included 14 benchmarking participants, including three Canadian provinces, nine US states, and two emirates from the United Arab Emirates. Countries and benchmarking participants could elect to participate in the fourth grade assessment, the eighth grade assessment, or both. Fifty-two countries and seven benchmarking participants administered the fourth grade assessment, and 45 countries and 14 benchmarking participants administered the eighth grade assessment.

Also, countries where students were expected to find the TIMSS assessments too difficult for their fourth or eighth grade students were given the option to assess students at a higher grade. Accordingly, three countries administered the fourth grade assessment to their sixth grade students and the eighth grade assessment to their ninth grade students.

Nationally representative samples of approximately 4,000 students from 150–200 schools participated in TIMSS 2011 at each grade level. More than

Armenia
Australia
Austria
Azerbaijan
Bahrain
Belgium (Flemish)
Botswana
Chile
Chinese Taipei
Croatia
Czech Republic
Denmark
England
Finland
Georgia
Germany
Ghana
Honduras
Hong Kong SAR
Hungary
Indonesia
Iran, Islamic Rep. of
Ireland
Israel
Italy
Japan
Jordan

Kazakhstan
Korea, Rep. of
Kuwait
Lebanon
Lithuania
Macedonia
Malaysia
Malta
Morocco
The Netherlands
New Zealand
Northern Ireland
Norway
Oman
Palestinian Nat'l Auth.
Poland
Portugal
Qatar
Romania
Russian Federation
Saudi Arabia
Serbia
Singapore
Slovak Republic
Slovenia
South Africa
Spain

Sweden
Syrian Arab Republic
Thailand
Tunisia
Turkey
Ukraine
United Arab Emirates
United States
Yemen

Benchmarking Participants

Alberta, Canada
Ontario, Canada
Quebec, Canada
Abu Dhabi, UAE
Dubai, UAE
Alabama, USA
California, USA
Colorado, USA
Connecticut, USA
Florida, USA
Indiana, USA
Massachusetts, USA
Minnesota, USA
North Carolina, USA

300,000 students participated in the TIMSS 2011 fourth grade assessment and a further 300,000 in the eighth grade assessment.

The TIMSS Trend Assessments in Mathematics and Science

IEA pioneered international comparative assessments of educational achievement to gain a deeper understanding of the effects of policies and practices across countries' different systems of education. IEA began its pioneering work in the 1960's with an international study of mathematics achievement, and mathematics has remained a major focus throughout its 50-year history of educational research. First administered in 1995, IEA's TIMSS is an integrated assessment of mathematics and science that has been conducted every four years since then. TIMSS is directed by IEA's TIMSS & PIRLS International Study Center at Boston College.

With assessments in 1995, 1999, 2003, 2007, and 2011, TIMSS has measured international student achievement in mathematics and science over a 16-year period, providing an unrivalled data resource for trends in mathematics and science achievement. All of the countries, institutions, and agencies involved in successive TIMSS assessments have worked collaboratively in building the most comprehensive and innovative measures of mathematics and science achievement possible, beginning in 1995 and improving with each successive assessment. Appendix A shows the participation in earlier TIMSS assessments by each TIMSS 2011 participant.

With its strong curricular focus and emphasis on policy-relevant information about the home, school, and classroom contexts, TIMSS is a valuable tool that countries can use to evaluate achievement goals and standards and monitor student achievement trends in an international context.

New Policy-relevant Context Questionnaire Scales

TIMSS 2011 provides extensive information about home supports and school environments for teaching and learning. In particular, in 2011 the trend cycles of IEA's TIMSS and PIRLS international assessments came together producing a synergy that led to advancements in the quality of background data collected by both projects. Because PIRLS (Progress in International Reading Literacy Study) also assesses students at the fourth grade, the alignment of the two projects provided the opportunity for countries to assess the same fourth grade students in reading, mathematics, and science in conjunction with the extensive background data collected by IEA assessments—most notably, allowing TIMSS

to benefit from the *PIRLS Learning to Read Survey*, completed by students' parents or caregivers.

Having almost 40 countries participate in both assessments required a great deal of coordination, innovation, and creativity, most notably in the area of background data collection. The *TIMSS 2011 Student Questionnaires*, *Teacher Questionnaires*, *School Questionnaires*, and *Curriculum Questionnaires* were developed jointly by TIMSS and PIRLS participants, including several joint meetings of the TIMSS 2011 Questionnaire Item Review Committee and the PIRLS 2011 Questionnaire Development Group. This effort yielded nearly 20 new context questionnaire scales about learning and teaching developed in parallel across reading, mathematics, and science. Underpinning a new approach to interpreting the questionnaire data, each context questionnaire scale was created using IRT methods, and results presented for three regions of the scale (most to least desirable) using scale score equivalents of response combinations to determine the cutpoints for the regions.

The TIMSS 2011 Science Assessment

The TIMSS 2011 science assessment is based on a comprehensive framework developed collaboratively with the participating countries. As described in the science chapter of the *TIMSS 2011 Assessment Frameworks* (Mullis, Martin, Ruddock, O'Sullivan, & Preuschoff, 2009), at each grade the science framework is organized around two dimensions: a content dimension specifying the domains or subject matter to be assessed within science, and a cognitive dimension specifying the domains or thinking processes to be assessed. The content domains and the topic areas within the domains are described separately for the fourth and eighth grades, with each topic area elaborated with specific objectives.

There are three content domains for the TIMSS 2011 fourth grade assessment:

- ◆ Life science;
- ◆ Physical science; and
- ◆ Earth science.

The eighth grade assessment has four content domains:

- ◆ Biology;
- ◆ Chemistry;

- ◆ Physics; and
- ◆ Earth science.

The following three cognitive domains describe the sets of thinking processes that students are likely to use as they engage with the science content:

- ◆ Knowing;
- ◆ Applying; and
- ◆ Reasoning.

These cognitive domains are the same for both grades, encompassing a range of cognitive processes involved in working scientifically and solving problems throughout the primary and middle school years.

Given the frameworks' broad coverage goals, the science assessment item pools were necessarily large—172 and 217 assessment items at the fourth and eighth grades, respectively—with approximately half multiple choice questions and half in a constructed response format in which students write their answers (see item counts by domain in Appendix B.1 and B.2). To keep response burden to a minimum, each student participating in the assessment responded to just a subset of the item pool, with IRT scaling used to estimate achievement on the assessment as a whole.

About 60 percent of the assessment items at each grade were retained from previous TIMSS assessments (2003 and 2007) to provide a foundation for measuring trends in science achievement across assessments; the remaining 40 percent were developed for TIMSS 2011.

Developing the assessment materials for TIMSS 2011 was a cooperative venture, involving the National Research Coordinators (NRCs) from the participating countries throughout the entire process. Having reviewed their national science curricula in the light of the TIMSS assessment approach, NRCs met to update the assessment framework for 2011 in terms of the balance of content and cognitive domain coverage and the assessment topics to be included. To develop the assessment items needed for the field test, the TIMSS & PIRLS International Study Center conducted an item-writing workshop for NRCs and their colleagues with particular backgrounds in science assessment and item development. Participating countries field tested the items and scoring guides with representative samples of students, and the results were scrutinized internally by the TIMSS 2011 panel of internationally recognized experts—the Science and Mathematics Item Review Committee.

Quality Assurance

The TIMSS science assessments were given to carefully selected and well-documented probability samples of students at the fourth and eighth grades. The student sampling for TIMSS 2011 was conducted with careful attention to quality and comparability. Staff from Statistics Canada and the IEA DPC worked with National Research Coordinators on all phases of the sampling activities. The Statistics Canada sampling experts, in conjunction with the TIMSS 2011 sampling referee (Keith Rust, Westat, Inc.), evaluated the quality of the samples and found high levels of compliance with sampling and participation requirements, with the exception of a few cases that are annotated in the report. Appendix C provides detail about the national target population coverage and sampling participation rates.

TIMSS 2011 made every effort to attend to the quality and comparability of the data through careful planning and documentation, cooperation among participating countries, standardized procedures, and rigorous attention to quality control throughout. For example, an extensive series of verification checks was conducted to ensure the comparability of the translations of the assessment items and questionnaires, detailed documentation was required to satisfy adherence to the sampling standards, and an ambitious quality assurance program was conducted to monitor the data collection.

TIMSS 2011 Reports

The results from TIMSS 2011 are presented in a series of major reports.

- ◆ This present report, *TIMSS 2011 International Results in Science*, summarizes fourth and eighth grade students' student achievement in each of the 63 participating countries and 14 regional benchmarking jurisdictions, and describes the educational contexts for science instruction. It includes trends in science achievement over time for participants in previous TIMSS assessments in 1995, 1999, 2003, and 2007 as well as student performance at the TIMSS International Benchmarks. Achievement results also are presented for science content and cognitive domains. The Science Report presents a rich array of information about students' backgrounds and attitudes toward science, the science curriculum, teachers' education and training, classroom characteristics and activities, and school contexts for science learning and instruction.

- ◆ As a complement to this volume, the *TIMSS 2011 International Results in Mathematics* (Mullis, Martin, Foy, & Arora, 2012) summarizes fourth and eighth grade students' mathematics achievement in each of the 63 participating countries and 14 regional benchmarking jurisdictions, and describes the educational contexts for mathematics instruction. It includes trends in mathematics achievement over time for participants in previous TIMSS assessments in 1995, 1999, 2003, and 2007 as well as student performance at the TIMSS International Benchmarks. Achievement results also are presented for mathematics content and cognitive domains. The Mathematics Report presents a rich array of information about students' backgrounds and attitudes toward mathematics, the mathematics curriculum, teachers' education and training, classroom characteristics and activities, and school contexts for mathematics learning and instruction.
- ◆ The *TIMSS 2011 Encyclopedia: Education Policy and Curriculum in Mathematics and Science, Volumes 1 and 2* (Mullis, Martin, Minnich, Stanco, Arora, Centurino, & Castle, 2012) describes national contexts for mathematics and science teaching and learning in the 63 countries and several of the regional benchmarking jurisdictions that participated in TIMSS 2011. A chapter prepared by each participant summarizes the structure of its education systems, the mathematics and science curricula and instruction in primary and secondary grades, the teacher education requirements, and the types of examinations and assessments employed. Together with selected supporting data about the countries curricula collected via online questionnaires, the chapters comprising the two volumes of the *TIMSS 2011 Encyclopedia* provide an important resource for helping to understand the teaching and learning of mathematics and science around the world, with particular emphasis on schooling through the eighth grade.
- ◆ The online publication, *Methods and Procedures in TIMSS and PIRLS 2011* (Martin & Mullis, 2012), describes the methods and procedures used to develop, implement, and analyze the results from TIMSS 2011 and is available from the TIMSS & PIRLS International Study Center's website: <http://timssandpirls.bc.edu>.

The fully documented TIMSS 2011 international database can be downloaded from the TIMSS & PIRLS International Study Center's website.

In addition, special analyses are being conducted using the TIMSS and PIRLS database of fourth grade students. This report, *TIMSS and PIRLS*

2011: Relationships among Reading, Mathematics, and Science Achievement—Implications for Early Learning, consists of in-depth analyses of fourth grade student achievement in reading, mathematics, and science in the countries that administered TIMSS and PIRLS to the same students in 2011. The report addresses four issues:

- ◆ Are primary schools providing a solid foundation in core subjects—reading, mathematics, and science?
- ◆ How does reading ability impact mathematics and science achievement?
- ◆ What are the characteristics of effective schools in reading, mathematics, and science? and
- ◆ How do homes support literacy and numeracy?

